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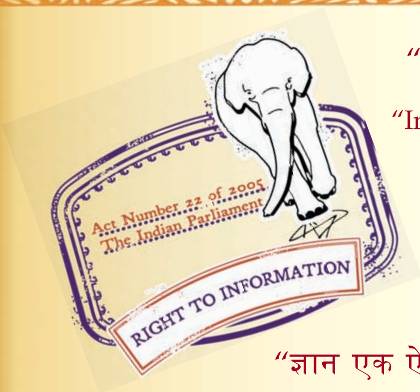

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CRITERIA FOR DESIGN OF ANCHOR BLOCKS FOR PENSTOCKS WITH EXPANSION JOINTS

(First Revision)

UDC 624·153·7·04 : 624·078·32 : 628·257

INDIAN STANDARDS INSTITUTION
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

 February 1985

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Indian Standard

CRITERIA FOR DESIGN OF ANCHOR BLOCKS FOR PENSTOCKS WITH EXPANSION JOINTS

(First Revision)

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Indian Standard

CRITERIA FOR DESIGN OF ANCHOR BLOCKS FOR PENSTOCKS WITH EXPANSION JOINTS

(First Revision)

0. FOREWORD

0.1 This Indian Standard (First Revision) was adopted by the Indian Standards Institution on 30 November 1984, after the draft finalized by the Water Conductor Systems Sectional Committee had been approved by the Civil Engineering Division Council.

0.2 Anchor blocks are required to hold pipe line at intervals along its length in order to:

a) prevent the pipe line sliding down the hill,

b) control the direction of expansion,

c) resist the unbalanced hydrostatic forces at a change of direction of the pipe line, and

d) prevent movement of the pipe line on account of vibration or water hammer pressures within permissible limits.

0.2.1 Design of anchor blocks require careful attention and judicious evaluation of various forces acting on the anchor block. This standard is prepared to help the designer in evaluating the forces acting on the anchor block and designing it for them.

0.3 This standard was first published in 1969. This revision has been made in view of the experience gained during the course of these years in use of this standard. Modifications made in this revision include the changes in the values of the sliding friction factor for stability analysis of anchor blocks and under seismic conditions some tension is allowed to make the design economical.

0.4 For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS : 2-1960*. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

*Rules for rounding off numerical values (*revised*).

1. SCOPE

1.1 This standard covers criteria for design of anchor blocks for penstocks with expansion joints.

2. NOTATIONS

2.1 For the purpose of this standard the following notations shall apply:

f = co-efficient of friction of pipe on piers,

f' = friction of expansion joint per m of circumference = $1{\cdot}5\ \mu\ wHe$,

w = unit weight of water in kg/m³,

A = cross-sectional area of pipe at anchor in m²,

A' = cross-sectional area of pipe above upper reducer in m²,

A'' = cross-sectional area of pipe below lower reducer in m²,

H = maximum head at any point including water hammer in m,

t = thickness of pipe shell in mm,

Q = flow in m³/s,

V = velocity in m/s,

g = acceleration due to gravity in m/s²,

P = dead weight of pipe from anchor uphill to expansion joint in N,

W = weight of water in pipe P in N,

P' = dead weight of pipe downhill from anchor to expansion joint in N,

W' = weight of water in pipe P' in N,

α_u = slope angle of penstock upstream of anchor,

α_d = slope angle of penstock downstream of anchor,

p = weight of pipe and contained water from anchor to adjacent uphill pier in N,

p' = weight of pipe and contained water from anchor to adjacent downhill pier in N,

d = inside diameter of pipe in mm,

a = cross-sectional area of pipe shell at uphill expansion joint in m²,

a' = cross-sectional area of pipe shell at downhill expansion joint in m²,

e = packing length in m,

μ = co-efficient of friction between packing and liner,

μ' = co-efficient of internal friction between foundation, concrete and foundation under saturated condition,

K = weight of anchor in N,

$\Sigma V'$ = total vertical forces,

τ = shearing strength in N/mm² under saturated condition,

a'' = area under compression in m², and

ΣT = total horizontal forces.

3. TYPES OF ANCHORS

3.1 Open Type — In this type of anchor the penstock is anchored to the concrete by rings as shown in Fig. 1.

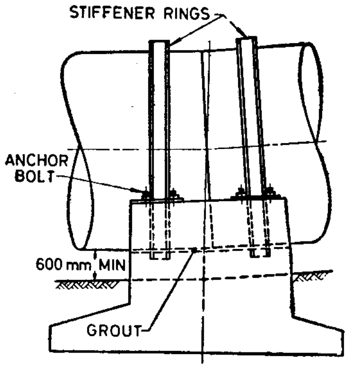


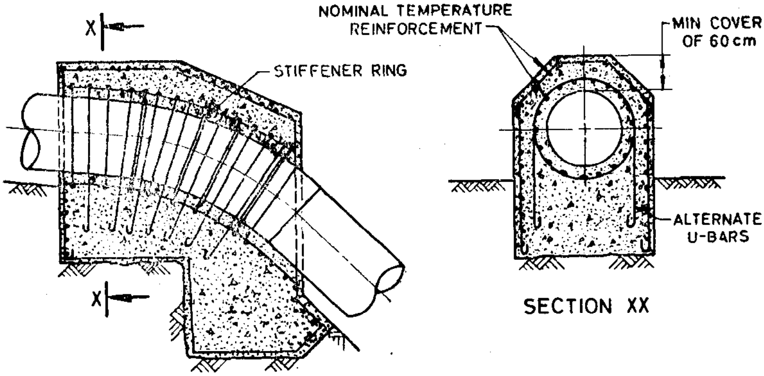
FIG. 1 TYPICAL OPEN TYPE ANCHOR BLOCK

3.2 Closed Type — In this type of anchor the pipe is embedded in concrete as shown in Fig. 2. Figure 2A shows an ordinary closed type of anchor block and Fig. 2B with sleeve type coupling.

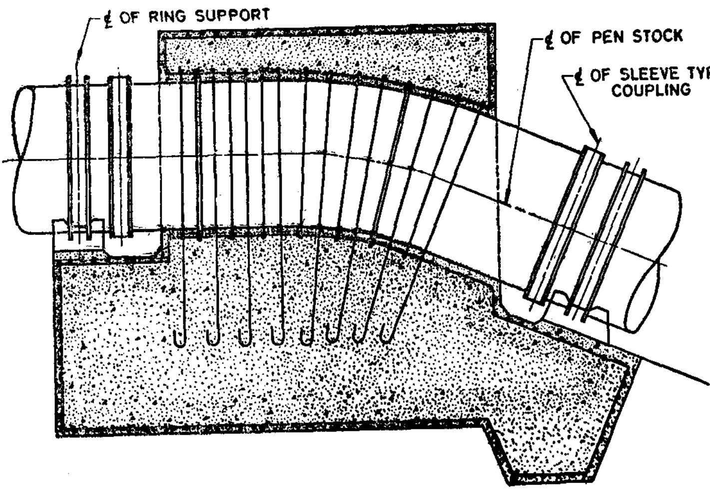
4. SPACING OF ANCHOR BLOCKS

4.1 For penstocks freely supported above ground surface or in open tunnel over the suitable intermediate supports, anchors shall be provided at all bends and at intermediate points in long tangents and where the distance between any two bends requiring anchors exceeds 150 m normally (up to 200 m in special locations).

4.2 For buried penstocks, anchor blocks shall be provided at horizontal bends with large deflection angles which will produce forces not exceeding the frictional and compressive resistance of soil, at vertical bends at summits and at bends adjacent to power house or pumping plant.



2A ORDINARY BLOCK



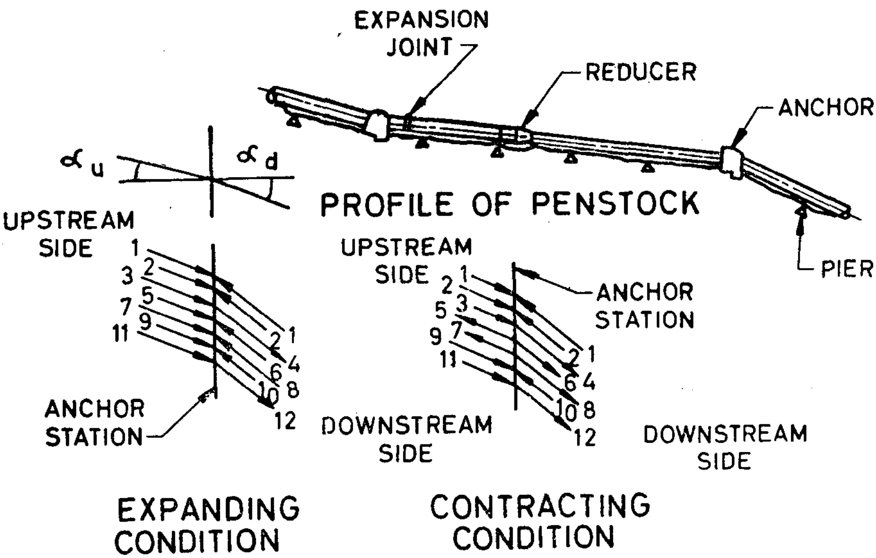
2B BLOCK WITH SLEEVE TYPE COUPLING

FIG. 2 TYPICAL CLOSED TYPE ANCHOR BLOCKS

5. LOADS AND FORCES ACTING ON ANCHOR BLOCKS

5.1 The anchor blocks shall be designed for the following loads and forces:

Load/Force	*Number Indicating Load/ Force in Fig. 3*
a) Hydrostatic force acting along axis of pipe on each side bend $F_s = WAH$	1
b) Dynamic force acting against outside of bend $F_d = \frac{QWV}{g}$	2
c) Force due to dead weight of pipe from anchor uphill to expansion joint, tending to slide downhill over pier $D_u = P \sin \alpha_u$	3
d) Force due to dead weight of pipe from anchor downhill to expansion joint tending to slide downhill over pier $D_d = P' \sin \alpha_d$	4



NOTE — The expansion joint may be provided in the end of a reach as indicated in the figure or in the middle of the reach.

FIG. 3 ACTION OF LOADS/FORCES ON ANCHOR BLOCK

Load/Force	*Number Indicating Load/ Force in Fig. 3*
e) Sliding fricting of pipe on piers due to expansion or contraction uphill from anchor $S_{pu} = f \cos \alpha_u \left(P + W - \frac{p}{2} \right)$	5
f) Sliding friction of pipe on piers due to expansion or contraction downhill from anchor $S_{pd} = f \cos \alpha_d \left(P' + W' - \frac{p'}{2} \right)$	6
g) Sliding friction of uphill expansion joint $S_{eu} = \frac{f'\pi\,(d + 2t)}{1\,000}$	7
h) Sliding friction of downhill expansion joint $S_{ed} = \frac{f'\pi\,(d + 2t)}{1\,000}$	8
j) Hydrostatic pressure on exposed end of pipe in uphill expansion joint $F_u = \frac{wH\pi t(d + t)}{10^6} = waH$	9
k) Hydrostatic pressure on exposed end of pipe in downhill expansion joint $F_d = wa'H$	10
m) Longitudinal force due to reducer above anchor $L_u = w\,H\,(A' - A)$	11
n) Longitudinal force due to reducer below anchor $L_d = w\,H\,(A - A'')$	12

5.2 Inertial forces due to earthquake shall be considered in accordance with IS : 1893-1984*.

5.3 Water hammer pressure at any point shall be computed as given in the 'Indian Standard Code of practice for design of water hammers in water conductor system' (*under preparation*).

NOTE — Until the standard under preparation is published, the matter shall be subject to agreement between the concerned parties.

5.4 The loads and forces specified in **5.1** shall be assumed to act in the directions shown in Fig. 3 for the conditions of expansion and contraction

*Criteria for earthquake resistant design of structures (*fourth revision*).

and for penstock full and empty condition. The block shall be tested for condition when seismic forces are absent and when they act in a direction so as to give the worst effect including uplift forces, if any. If prestressed anchors are provided, the prestressing forces shall be considered in design of the block.

5.5 Value of *f* co-efficient of friction of pipe on piers may be taken as given below:

Steel on concrete (cradle supports)	0·60
Steel on concrete with asphalt roofing paper in between	0·50
Steel on steel, rusty plates	0·50
Steel on steel, greased plates	0·25
Steel on steel with two layers of graphite service sheets in between	0·25
Rocker supports, deteriorated	0·15
Roller supports, deteriorated	0·10
Concrete on concrete	0·75

5.5.1 The co-efficient of friction between the packing and the liner may be taken as 0·26.

6. ANCHOR BLOCK FOUNDATION

6.1 Anchors should preferably be founded on a rock base. Wherever rock is available at great depths, the stability of overburden material as excavated for anchor block foundation shall be checked against sliding as an earthen slope with anchor block on it and in its natural condition.

6.2 Stable slope cuts shall be provided around the anchor block location so as to safeguard against the possibility of a slide of the slope cut damaging the anchor block foundation.

6.3 Precautions shall be taken to prevent such erosion by neighbouring streams as would adversely affect the foundation of the anchor block.

6.4 In high altitude areas where permafrost conditions exist, there are chances of alternate freezing and thawing in the soil. Adequate measures shall be adopted to account for the volume change in the foundation to ensure stability.

7. DESIGN CRITERIA

7.1 The foundation of anchor blocks shall be designed so that the maximum pressure on the foundation shall not exceed the allowable bearing pressure of the soil, determined as specified in IS : 1904-1978* which shall be confirmed by tests. The permissible bearing capacity may be increased in accordance with IS : 1893-1975† for seismic conditions.

7.1.1 When the profile is sloping, the safe bearing capacity shall be reduced to take into account the decrease due to non-normality of resultant to the surface in accordance with IS : 6403-1971‡. The angle set up by resultant with ground shall not be less than 30° for stability of soil below anchor.

7.2 Anchor blocks shall be designed safe against sliding on foundation. The sliding fricition factor computed by dividing the total horizontal forces by total vertical forces shall be less than that given below:

Surface	*Sliding Factor*
Concrete on rock	0·50
Concrete on gravel	0·40
Concrete on sand	0·33
Concrete on clayey soil	0·25

7.2.1 In case the anchor blocks rests on solid rock, without any weak planes capable of sliding, the sliding factor shall be designed for 0·75. Where however, weak seams or joints along which sliding may be apprehended in the rock below, the stability should be checked by the following shear friction formula:

$$\text{Shear friction factor} = \frac{\mu' \Sigma V' + \tau a''}{\Sigma T}$$

NOTE — The weight of the anchor blocks may get reduced if the anchor block and rock above of such a seam is anchored into the rock below the seam.

7.3 The design of the anchor blocks shall be such that the resultant of all the forces falls within the kern of the base. For anchor blocks with stepped bottom the designs shall be made so that the resultant falls within the kern of the projection of the anchor base on a plane perpendicular to the resultant (*see* Fig. 4). Under seismic conditions, however, tension up to 0·2 N/mm^2 may be permitted. The bearing pressure should be checked neglecting area under tension.

*Code of practice for structural safety of buildings: Foundations (*second revision*).

†Criteria for earthquake resistant design of structures (*third revision*).

‡Code of practice for determination of allowable bearing pressure on shallow foundations.

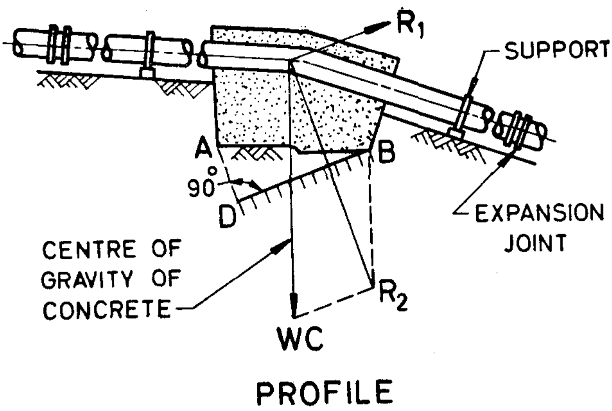


FIG. 4 STABILITY OF ANCHOR BLOCK WITH STEPPED FOUNDATION

7.4 The anchor block reinforcement shall be designed for the forces indicated in **5.1.** However, even if no reinforcements are indicated by such calculations, nominal reinforcement shall be provided. A suggested pattern of reinforcement is shown in Fig. 2.

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